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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 220

Contribution from the Office of Public Roads, Logan Waller Page, Director.
June 7, 1915.

ROAD MODELS.

Prepared by the Office of Public Roads.

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INTRODUCTION.

The Office of Public Roads of the United States Department of Agriculture made an exhibit of road models for the first time in 1909 at the Alaska-Yukon-Pacific Exposition. The aim was to put on view such striking examples in miniature of model roads that visitors would not only appreciate the beneficent effects of improved roads but would, at the same time, be able to understand the methods of their construction.

Since the Alaska-Yukon-Pacific Exposition closed, the exhibit of the Office of Public Roads has been displayed at Omaha, Nebr., during the National Corn Exposition; at Knoxville, Tenn., during the Southern Appalachian Exposition; at Chicago, Ill., during the National Land and Irrigation Exposition; at New York City during the Travel and Vacation Exposition and the Domestic Science Exposition; at Atlantic City, N. J., during the American Road Congress; at Lethbridge, Alberta, during the International Dry-Land Congress; at Buenos Aires, Argentina, during the International Agricultural Exposition; at Turin, Italy, during the International Exposition;

NOTE.—This bulletin contains illustrations and descriptions of the models in miniature of roads, bridges, and culverts and of road machinery exhibited by the Office of Public Roads at expositions and fairs and on railroads. Methods of construction are discussed.

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and at various other expositions and fairs. The models have also been displayed on road trains at all important places along the route of the Pennsylvania Railroad in the State of Pennsylvania and along the entire system of the Southern Railroad, also along the St. Louis & San Francisco Railroad, the Atlantic Coast Line, the Nashville, Chattanooga & St. Louis Railroad, and the New York Central & Hudson River Railroad. A comprehensive exhibit of these models, illustrating all standard types of construction, has been installed at the Panama-Pacific Exposition in San Francisco, Cal.

The models, as a rule, are constructed on a scale of 1 inch to the foot, so that each model is one-twelfth the size of the actual road which it represents. Modifications of the methods of construction may be necessary to meet local conditions. Advice and information relating to road construction, maintenance, or improvement in any section of the country may be obtained upon application to the Director of the Office of Public Roads.

The descriptions of the models are so arranged in this bulletin as to present the historic development of road building. The Roman road is described first, and then descriptions are given successively of the French roads, after the ideas of the Romans and of Trésaguet, the roads of MacAdam and Telford, and finally the various types of modern construction. Among the latter are models showing brick, concrete, asphalt-block, macadam, sand-clay, gravel, and earth roads. There are other models showing the processes of maintenance, resurfacing, and bituminous macadam construction by the mixing and penetration methods. One model shows the various methods of draining and strengthening unstable foundations, while another shows a typical method of treating gravel or macadam roads to make them dustless and to prevent their disintegration under automobile traffic. Two models recently added to the series illustrate, respectively, road location and roadside treatment.

ROMAN ROADS.

The Romans began building roads on a large scale more than 300 years before the Christian era. The Appian Way, one of the most celebrated of their roads, was begun in 312 B. C., by Appius Claudius Cæcus. This road led from Rome to Capua, a distance of 142 Italian miles. It was later continued to Brindisi, making the total distance 360 miles. Rome continued as a great road-building nation for about 600 years, and fragments of some of its roads still remain. The Appian Way is said to have been in good condition more than 800 years after its construction.

The Roman construction was not uniform, though always extremely massive. The general form of construction employed during the

reign of Cæsar Augustus, when Roman road building seems to have reached its height, was a massive road from 16 to 30 feet wide, from 3 to 4 feet thick, and laid in 3 or 4 courses. The first course was almost invariably of large, flat, field or quarry stones laid on the earth subgrade, except in swamps, where poles, logs, brush, or even boards were used beneath the stone course. The other courses varied extremely with the available material and the period and importance of the road. Either small stones, with and without mortar, or gravel, broken brick, tiles, etc., were used for the second and third courses. The surface or wearing course consisted of well-cut, irregular, close-fitting polygonal blocks on a few of the more important roads, but more often it consisted of uncut stones, not unlike our cobblestone pavements, or of gravel, and in some cases of a mixture of sand and clay or clay and gravel.

Some of the more important roads near Rome were practically lined with temples, porticoes, and statues. On all roads inscribed milestones were placed at regular intervals.

Plate II, figure 1, shows a model of the Appian Way. This is the highest type of road constructed by the Romans.

Section A shows the contignatum pavimentum, composed of lime and sand, straw, rushes, or reeds, and sometimes laid on sills or boards.

Section B shows the statumen, or foundation, composed of two courses of flat stones laid dry or in lime mortar. The depth of this course was from 16 to 18 inches.

Section C shows the rudus, or rubble, composed of broken stone mixed with lime in the proportion of 1 part of lime to 3 parts of stone. Sometimes the material was taken from old buildings. This course was laid from 6 to 9 inches deep.

Section D represents the nucleus, composed of coarse gravel and lime used hot, or bricks, potsherds, or broken tile mixed with lime and covered with a thin layer of lime mortar.

Section E shows the summa crusta, or pavimentum, consisting of polygonal blocks joined with the greatest nicety. This course was about 6 inches deep and about 16 feet wide.

Section F indicates the curbs, which were 2 feet wide and 18 inches high, with mounting blocks as shown at G. These blocks also served as seats for travelers.

Section H shows a side road, the surface of which was composed of gravel flushed with mortar. The width was from 6 to 8 feet.

FRENCH ROADS.

From the viewpoint of construction, road building in France may be divided into three periods—the period of Roman influence, the period of Trésaguet, and the modern period.

FRENCH CONSTRUCTION PREVIOUS TO 1775 (ROMAN METHOD).

By the time that road building was revived in France, in the seventeenth century, the Roman methods of road building had been greatly modified, though the Roman form, especially in the foundation, was still retained. Under the ministry of Colbert (1660–1669) as controller general of finances, about 15,000 miles of stone roads were built, practically all with an undrained foundation consisting of one or more layers of large flat stones placed in the bottom of a trench-like excavation. These stones were then covered with a thick layer of more or less finely broken stone. As no systematic maintenance was attempted, the roads rutted badly, and it was only rarely that the broken stone consolidated properly. The total thickness of the roads was from $1\frac{1}{2}$ to $2\frac{1}{2}$ feet.

Plate II, figure 2, illustrates the type of road constructed in France previously to 1775. This type was modeled on the Roman system.

Section A shows the earth foundation, which was flat.

Section B represents the first course. This course was composed of flat stones laid by hand in two or more layers. The total width of this course was 18 feet and the depth was from 9 to 10 inches.

Section C shows the second course, a layer of small stones, which were broken in place with hand hammers.

Section D shows the finished surface. This course was composed of stones broken by hand into sizes smaller than the underlying material. It was left to be consolidated by traffic. The total thickness of the road in the center was from 18 to 20 inches and at the sides from 12 to 14 inches.

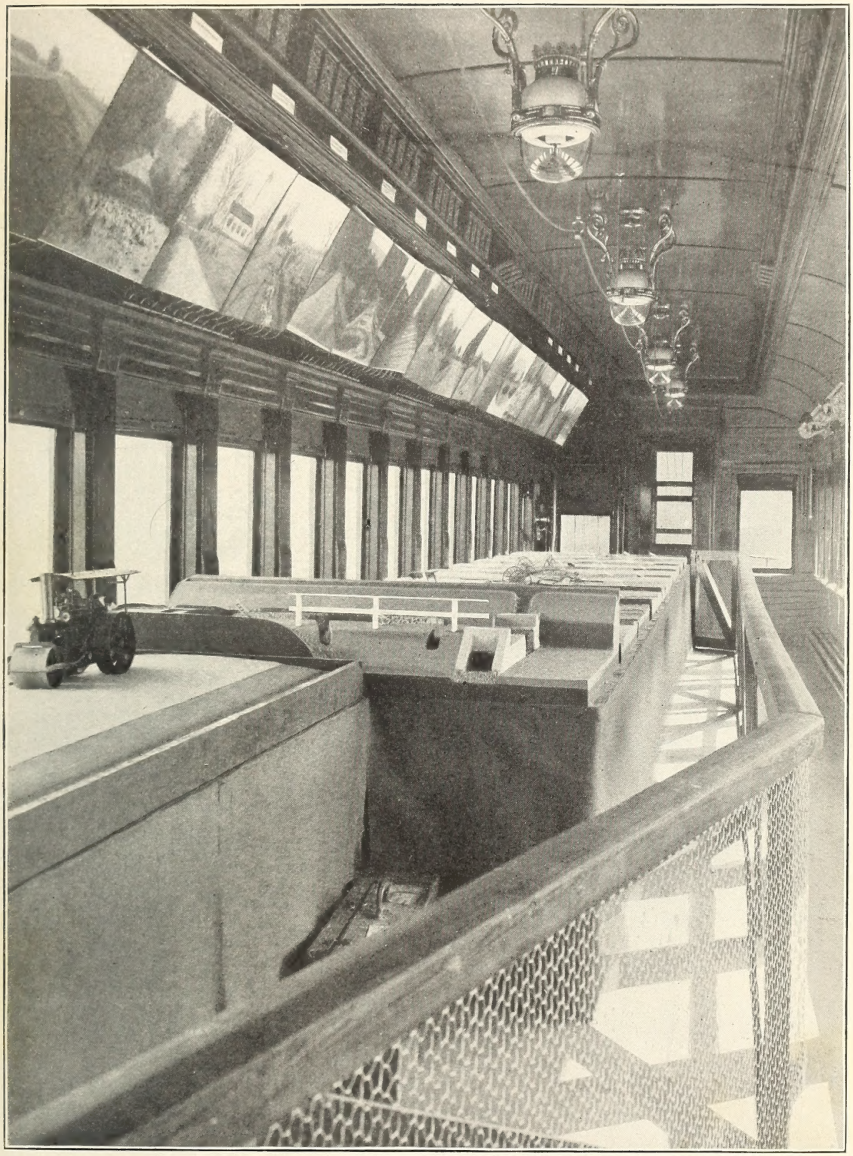
TRÉSAGUET METHOD.

About 1775 a form of construction, supplemented by continual maintenance, came into prominence in France. It had long been advocated by Pierre Marie Jérôme Trésaguet, a noted French engineer. He held that good drainage and systematic maintenance were absolutely necessary for good roads. By providing a properly crowned and drained foundation, he reduced the required thickness more than one-half and provided a better and more serviceable road. The small stones were broken more uniformly and, by a little attention after placing, soon bonded under the traffic. The resulting roads were smooth and afforded comfortable traveling.

Plate III, figure 1, illustrates the type of road constructed in France by Trésaguet from 1775 to 1830.

Section A shows the earth foundation shaped parallel to the finished surface.

Section B represents the first course, which was composed of flat stones laid on edge lengthwise across the road and beaten to an even surface. The depth of this course was about 5 inches.



VIEW OF A TRAIN EXHIBIT FROM THE OFFICE OF PUBLIC ROADS.

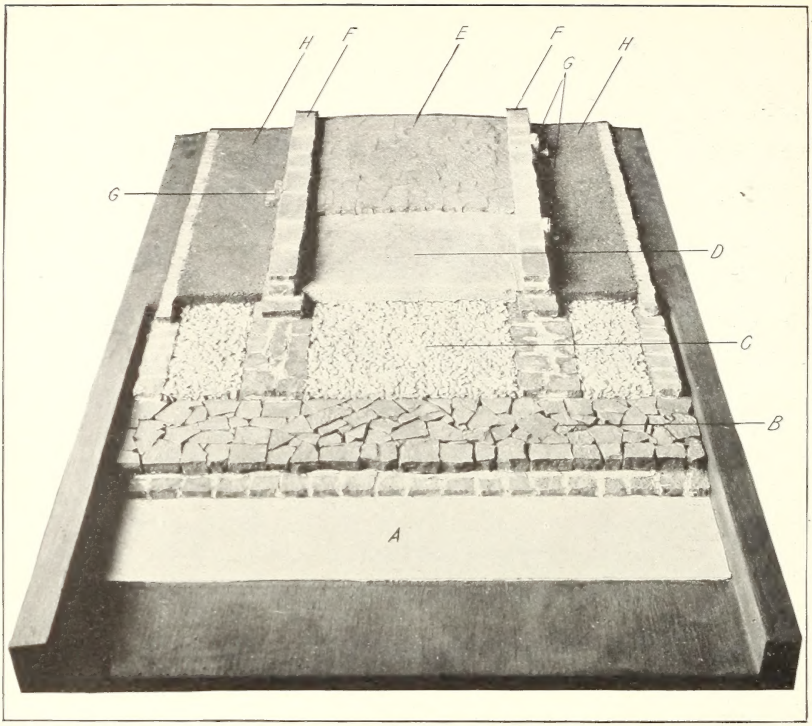


FIG. 1.—MODEL SHOWING THE APPIAN WAY (300 B. C.).

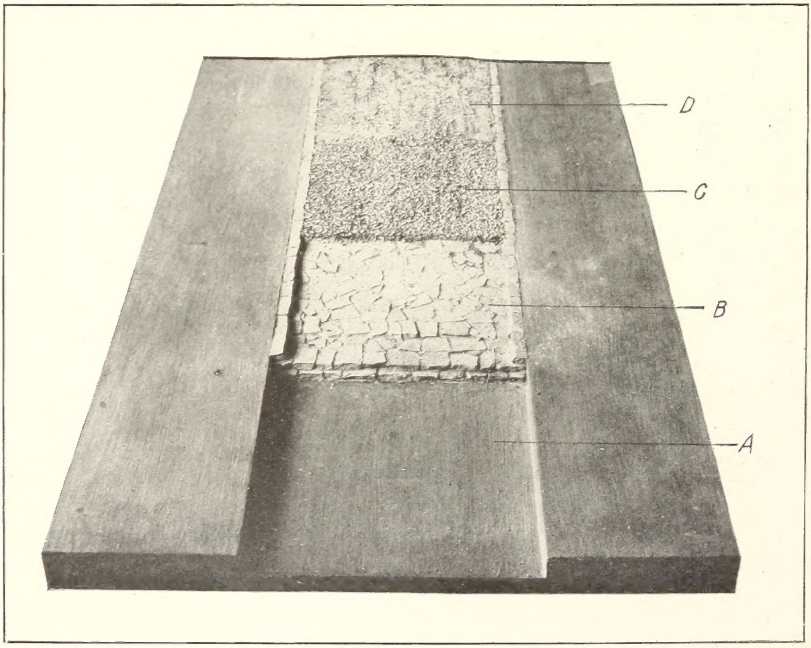


FIG. 2.—MODEL SHOWING A FRENCH ROAD BUILT BEFORE 1775 (ROMAN METHOD).

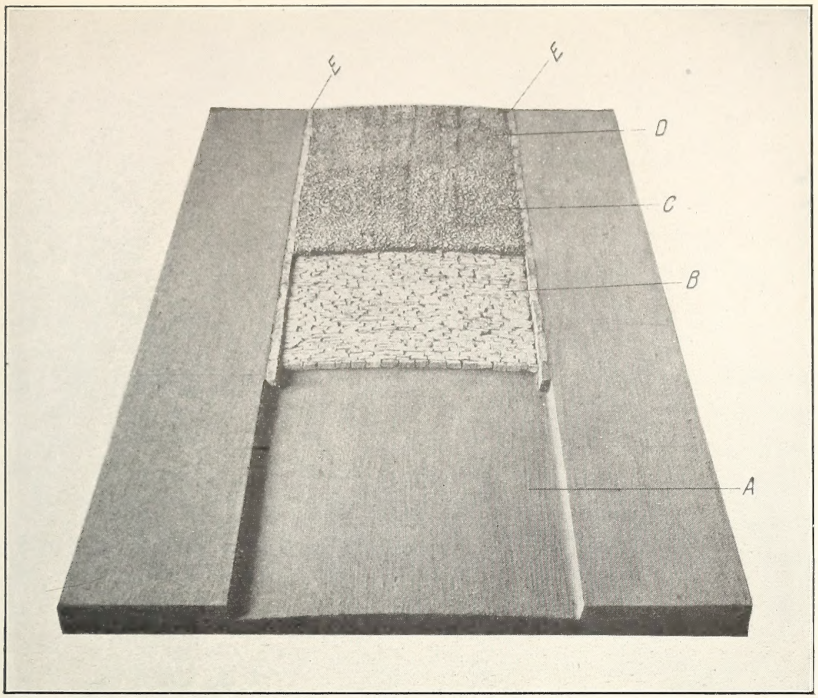


FIG. 1.—MODEL SHOWING A FRENCH ROAD OF TRÉSAGUET, BETWEEN 1775 AND 1830.

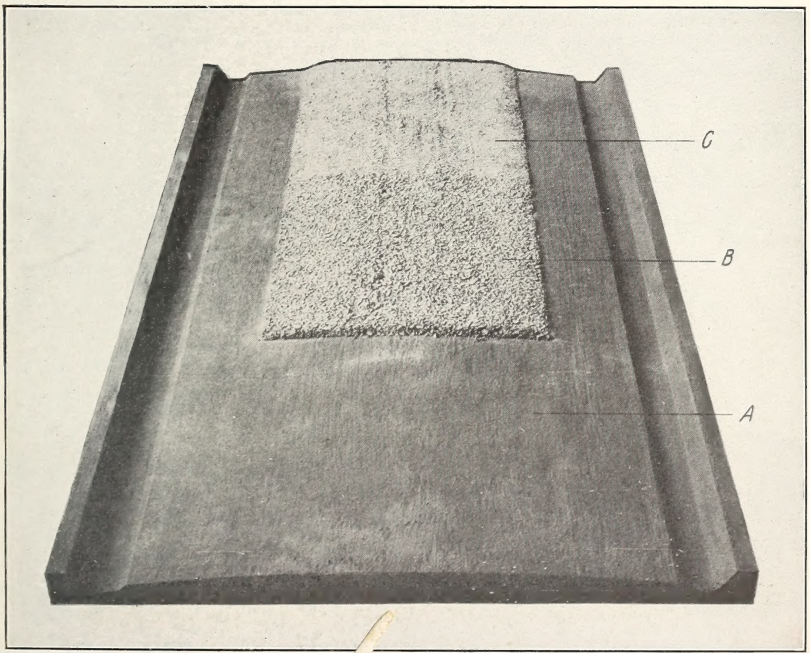


FIG. 2.—MODEL SHOWING A MACADAM ROAD OF THE TYPE BUILT BY MACADAM (1816).

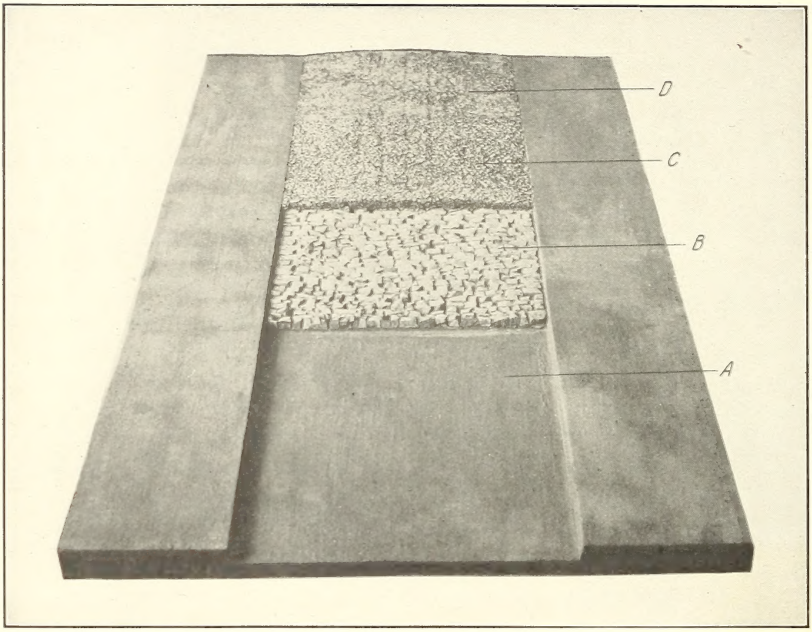


FIG. 1.—MODEL SHOWING A TELFORD ROAD OF THE TYPE BUILT BY TELFORD (1820).

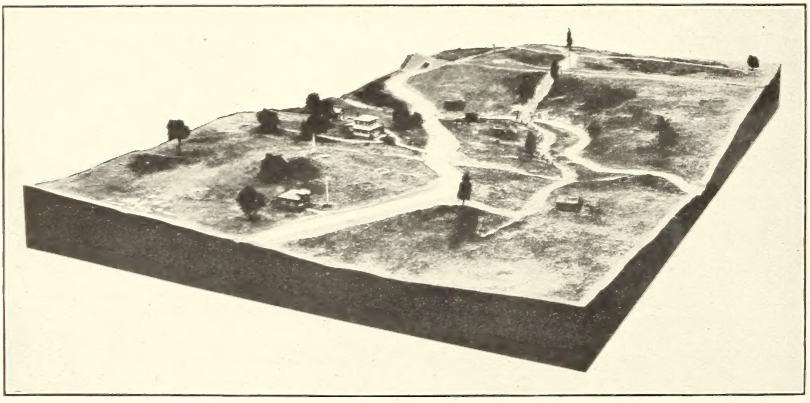


FIG. 2.—MODEL SHOWING LOCATION AND ALIGNMENT; OLD AND NEW ROADS.

Section C shows the second course, which was of small stones laid and beaten by hand hammers. The finished layer was composed of broken stones about the size of walnuts and was spread with a shovel.

Section D represents the finished road as consolidated by travel. The crown was made 6 inches, the width 18 feet, and the total thickness about 10 inches.

E shows the curbs, which were composed of rough, flat stones, set on edge. The upper edge was made flush with the road surface.

MACADAM METHOD OF CONSTRUCTION.

The macadam method of construction was introduced in England and Scotland by a Scotchman, John Loudon MacAdam (1756–1836). The chief features of MacAdam's construction were a raised, thoroughly drained, and crowned earth foundation, stone broken to a uniform size not exceeding 1½ inches, and no addition of binding material to the broken stone. MacAdam also insisted that the finished road should have a slight crown and that broken stone when spread on the road should be kept raked smooth until thoroughly consolidated by traffic. This form of construction continued practically unchanged until the introduction of the road roller, about 1870.

During the past 40 years the methods of construction and maintenance have been greatly modified, yet the term "macadam" is still applied to broken-stone roads.

At the present time the macadam road is built in courses, with the coarser stones at the bottom and the finer on top. Stone screenings or sand are used for binding. In practically every case the stone is broken by machinery.

Plate III, figure 2, illustrates a macadam road of the type constructed during the first period of macadam construction, which began about 1816.

Section A shows the earth foundation, which was always made higher than the surface of the adjacent ground so as to facilitate the escape of water from the foundation and the surface.

Section B shows the layer of hand-broken stone, with a depth of 10 inches. This stone was broken to sizes weighing about 6 ounces, and no stone was used that exceeded 1½ inches in its greatest dimension. The surface of the road was raked regularly during the process of consolidation. No rollers were used, and the stone was compacted by traffic.

Section C shows the finished road, from 16 to 18 feet wide. The crown was raised from 4 to 6 inches. MacAdam contended that the stones would lock or bond by virtue of their angularity and so make a water-tight crust, and that it was neither necessary nor desirable "to bond a road with earth, clay, chalk, or other material that would imbibe water or be affected by frost." The surface

of the road was kept even and smooth by the addition of fresh material where necessary. This material was placed on the road in thin layers in damp weather in order that the new material might more readily bond and incorporate with the old.

TELFORD METHOD OF ROAD BUILDING.

This form of construction takes its name from the celebrated engineer, Thomas Telford (1757–1834), who, besides doing many other notable things, constructed 920 miles of roads in the Highlands of Scotland and also a large mileage in the mountainous sections of Wales and in the north of England. To-day the chief characteristic of the telford road is a base of fairly regular stones, about 3 by 5 by 7 inches in their smallest dimensions, placed by hand on the wider of the long narrow faces and with the greatest dimension perpendicular to the axis of the road. The blocks are then "keyed in" by filling the interstices with stone spalls, chips, or small gravel. Any projecting points are broken off. On this base is placed a wearing surface of broken stone from 4 to 7 inches deep. Originally the telford road was constructed with a flat subgrade, and a slight crown was obtained by using larger stones in the center. In present construction, however, the subgrade is given the same crown as the finished road, and stones of uniform size are used throughout. Formerly, too, the wearing surface was placed and consolidated in the same manner as the wearing surface of the old macadam road.

The telford base is used very generally in the construction of important roads in Austria-Hungary, Germany, Russia, Switzerland, and the Scandinavian countries. Some of the roads of England and Scotland which were formerly macadam are proving too weak for the present heavy traffic and are being relaid with a telford base.

Plate IV, figure 1, illustrates a telford road as constructed during the first period, which began about 1820.

Section A shows the earth foundation, from 16 to 20 feet wide, and flat.

Section B represents the telford base, composed of stones about 7 inches in depth. No stone more than 3 inches wide was placed at the top.

Section C shows the top course, about 7 inches thick at the crown. It was composed of hand-broken stone, in pieces not heavier than 6 ounces, which would pass through a circular ring not larger than 2½ inches in diameter.

Section D shows the finished road, bonded with 1 inch of gravel. The crown was made 6 inches for the road, which was surfaced to a width of 18 feet.

LOCATION AND ALIGNMENT.

When a new road is to be built, or an old road rebuilt, the profile should be established and the curves plotted by a competent engineer. The sharp curves and steep grades should be eliminated by a proper alignment or by cuts and fills. When a grade exceeds 6 feet in 100 feet, it is considered excessive for heavy traffic. A curve with less than a 200-foot radius is considered dangerous for fast traffic. Embankments, trees, and shrubs which obscure the line of sight on sharp curves should be cut back in order that rapidly moving vehicles approaching each other may be able to pass without accident.

In selecting the location for a new road, low, swampy ground or ground subject to overflow should be avoided. The road should be located on solid ground. In mountainous or hilly sections it should be located on the sidehill slopes, with southern or western exposure, where the natural drainage is good, and not in creek or river bottoms.

The road should be as straight as possible, but a good grade is preferred to straightness. Generally a road should be located around long steep inclines instead of over them. If this is impracticable then the length of the road up the incline should be increased sufficiently to obtain a good grade. Dangerous railroad grade crossings should be avoided by relocation of the road or by overhead bridges or underpasses.

Plate IV, figure 2, illustrates the relocation of an old road. To the right is shown the old earth road, with such characteristic features as steep grades, poor alignment, dangerous grade crossings, unsafe wooden bridge, and inadequate drainage. The dilapidated farm buildings and the old district schoolhouse featured on the model, with their unsightly and insanitary surroundings, are the usual accompaniment of such a road. To the left is shown the new road, located on higher ground, along sidehill slopes, with easy grades and pleasing, practical alignment. The grade crossing has been eliminated. A bridge and permanent culverts have been built and good drainage provided as well as a well constructed and maintained macadam surface. The sightly farm buildings and attractive consolidated district schoolhouse are supplied with pure water by means of windmill and reservoir.

FOUNDATION, OR SUBGRADE, AND SHOULDERS.

In the construction of all types of gravel or macadam roads it is necessary, in order to obtain the most economical results, to prepare the foundation, or subgrade, and shoulders of the road carefully. After the subgrade has been properly shaped and before any broken stone or other material is put on, it should be thoroughly rolled and compacted. Water-puddling may be resorted to in case the soil

requires it. All hollows and depressions which develop during the rolling should be filled with good material. If soft or spongy places develop during the rolling, the soft or spongy material should be taken out and replaced with good material and the subgrade again rolled. This process of filling and rolling is repeated until no depressions develop and the subgrade has been brought to its proper elevation, which is as much below the established grade as the thickness of the surfacing course to be used. The shoulders ought also to be rolled in the same manner, but in places where the character of the material makes the use of a heavy roller impracticable, a lighter roller may be used. The shoulders are built at the same time as the subgrade and with it form a trench to hold the surfacing material. They may be built either by excavation or by piling up earth as the work progresses. The shoulders also serve to widen the road for the passing of vehicles. They are usually given a sharper slope than the paved portion of the road.

Plate V, figure 1, shows a model illustrating several methods of road drainage. It will be noted that the roadbed is located partly in a cut and partly on a sidehill.

Section A shows a surface ditch (*h*) at the top of the slope, a side drain (*c*) opening into a culvert (*a*) with a drop inlet (*b*), a telford base, a section of guard rail (*g*), and a shoulder drain (*d*).

The surface water falling on a large area sloping toward the road is often kept from the road and out of the road gutters, where it usually does considerable damage, by a surface ditch such as (*h*). The side ditch (*e*) is used to gather the water originating on or along a roadway and to carry it to points of outlet. As a general rule the bottom of the ditch is lower than the low point on the subgrade of the road. The size of the ditch varies with the amount of water it is necessary to accommodate. The shape of the ditch varies with climatic, soil, and topographic conditions. The side drain (*c*) is constructed to carry off the ground water which is often found in hilly sections. In the model the trench is represented to be 2½ feet deep, 12 inches wide at the bottom, and 18 inches wide at the top. On the bottom of the trench is placed tile pipe, usually 6 inches in diameter. The pipe is laid without cement, and loose stone is carefully filled around the sides and top of the pipe to the top of the trench. The side drain empties in some suitable outlet. For example, the one in this model empties in a drop inlet (*b*), which also serves as an outlet to the surface and side ditches. The drop inlet empties into a culvert (*a*), which carries the water under the road. This type of inlet prevents the bank from sliding and closing the culvert, which sometimes happens in hilly sections.

The purpose of the shoulder drain (*d*) is to permit water to escape from the subgrade during or immediately after the construction of a

gravel, macadam, or other road of crushed stone. These drains are generally a little deeper than the subgrade and slope toward the side ditches, to which they carry the water. They are filled with crushed stone to a depth of 6 or 8 inches and are covered over with earth. The shoulder drains are required in clay soils and are placed at the low points in the grade as well as at frequent intervals on flat grades.

The telford base is extensively used in locations on swampy or marshy ground.

The guard rail shown in the model is desirable along steep slopes to protect travelers. The fence is painted to prolong its life. The white color enables the public to discern it at night. The posts are about 6 inches in diameter and about 7 feet long, and are set in the ground to a depth of 3½ feet. About 18 inches from the ground a plank, 2 by 6 inches, is notched into the posts. The top rail is then placed about 18 inches above the top edge of this plank. It may be either 4 by 4 inch timber, notched into the top of the post, or a plank, 2 by 6 inches, spiked to the top of the post, which has been sawed off to a slope of 3 inches.

Section B shows a V drain base with a side outlet.

The V drain base, when used in through cuts, is cheaper than the telford method with two side drains, especially in a section of country where field stone abounds. It, like the telford, is often used in wet and spongy ground. The water flows to and along the point of the V drain (*i*) until a suitable outlet can be secured. The center is usually excavated 2 feet and the sides about 16 inches below the finished grade. The material excavated is thrown to the sides, forming the shoulders. In swamp sections it is sometimes necessary to haul material for the shoulders. The V drain is then filled with stone to a depth of 18 inches at the center and 10 inches at the sides. These stones grade from 8 inches in thickness down to a few inches. The large-sized stones are placed at the bottom, while the small stones are used at the top. The surface should then be rolled and the surfacing material spread and rolled. V drains are sometimes built of brickbats, slag, or even sand, or any material that will permit the water to seep rapidly to the point of the V. This type of construction permits the use of field stone of an inferior type and assists in clearing many farm lands of an otherwise waste product.

Section C shows a center drain with laterals and cobble gutters.

The center drain with laterals, sometimes called a blind or French drain, furnishes another mode of draining the foundation of a road. As with the V drain, the water is brought to the center of the road and conducted to some suitable outlet. The model shows these drains about 2 feet deep, about 12 inches wide at the bottom, and about 18 inches wide at the top. A drain tile is placed at the bottom

of the trench, which is then filled with stones from a few inches up to 8 inches in thickness.

The cobble gutters (*f*) show an effective way of carrying away surface water on steep grades. The stones vary in thickness from 8 to 12 inches and are laid on a sand or gravel base. They are well rammed and given a coat of sand, which is carefully swept in, and then the stones are rammed again. These gutters are easily cleaned and carry the water along rapidly without damage to the road by washing.

EARTH AND SAND-CLAY ROADS.

The mileage of roads in the United States is so great and the traffic on many of the country roads so light that it will be impossible and impracticable for years to come to improve more than a small percentage of the roads with a hard surface. This does not mean, however, that all other roads should be neglected. They should, as rapidly as possible, be improved to the extent warranted by their importance. The common clay roads may be greatly improved by a little judicious grading and systematic maintenance.

Frequently, especially in the South, many of the country roads may be improved, for all practical purposes, by incorporating sand or clay, as the case may require, with the surface soil of the road. Thousands of miles of sand-clay roads have already been built in the Southern States at an average cost of about $750 per mile. These roads meet the present needs of many localities as well as would a more expensive form of construction.

EARTH ROADS.

Plate V, figure 2, illustrates the construction and maintenance of an earth road.

Section A shows the old and unimproved roadbed. The surface is characteristic of altogether too many earth roads. The center is lower than the sides, which makes it impossible for the water to run toward the ditches; and even if this were possible there are no roadside ditches to carry it away. In consequence, the road is usually full of ruts and mudholes.

Section B illustrates a section of earth road under improvement, with a road machine or grader. The width of the section shown is equivalent to about 33 feet of finished surface from ditch to ditch. The use of a reversible road machine is shown in opening roadside ditches and in shaping the road surface so that it will shed water. The work of this machine is equivalent to the labor of many men, and it is done far better than possible with picks and shovels. An earth road should have a width of at least 20 feet, preferably 24 to 30 feet. If the road is narrow, wagons are likely to use the center of it and make deep ruts. The surface drainage is provided for by giving the road an average crown or slope from center to sides of 1 inch

to the foot. Side ditches should be built, as shown in section B, on all earth roads except sandy sections, which are best when damp. Ditches can be made and maintained with a road machine, but care should be taken that they have a fall sufficient to carry the water along the side of the road. Through wet and swampy land it is often necessary to raise the roadbed above the general level of the country in order to secure drainage.

Section C illustrates an earth road which, though surfaced by a road machine, has rutted under heavy traffic and is being maintained by the split-log drag. In the road illustrated by sections B and C the crown or slope from the center to the sides is equivalent to 1 inch to the foot.

For continuous maintenance the split-log drag shown on the model has been devised. This miniature drag has been built to the same scale as the road model, 1 inch to the foot. The full-sized drag can be made best from a log 7 or 8 inches in diameter and from 6 to 8 feet long. The log should be carefully split, and the halves, with the flat sides vertical and facing to the front, connected by stakes. The halves, though of the same length, are joined so that one end of the rear half is from 16 to 20 inches nearer the center of the road than the corresponding end of the front half. An ordinary trace chain and a set of doubletrees are then attached in such manner that when the horses move forward the drag will be pulled along the road at an angle of about 45 degrees, with the forward end nearest the ditch in order to move the earth toward the road center.

The drag should be light enough to be lifted by one man. The best material is dry red cedar, though red elm and walnut are excellent, while box elder, soft maple, elm, or willow are superior to oak, hickory, or ash. A platform is usually placed on the cross stakes to strengthen the drag and furnish a place for the driver to stand. After a little practice a man can learn how best to shift his weight so as to make the drag cut, spread, and pack the earth properly.

Filling the ruts by dragging up one side of the road and down the other is all that should be undertaken the first time, but this should be repeated after each heavy rain. As a mile of road can be dragged in a few hours, this method of maintenance is simple and inexpensive. If the drag is used in conjunction with the road machine, fairly good earth roads can be built at a small expense. Dragging is done for 50 cents per mile in some parts of the country. At this rate a mile of earth road can be dragged once a month for $6 annually. Some remarkable results have been accomplished with the drag without the aid of the road machine. Farmers' Bulletin 597,[1] "The Road Drag and How to Use It," deals fully with this subject.

[1] Copies of this publication will be sent free to persons applying to the Secretary of Agriculture, Washington, D. C.

SAND-CLAY ROADS.

Plate VI, figure 1, illustrates the construction of a sand-clay road 16 feet wide and 8 inches thick when compacted. The crown, as shown, is 1 inch to the foot.

Section A represents an unimproved sand road about 33 feet wide; section B, the road slightly rounded to receive the clay; section C, the road covered with clay to a depth of 6 inches; section D, the harrowing or mixing process; and section E, the completed road. The process is as follows:

The road is first shaped, then covered with from 4 to 6 inches of clay and worked with a disk or tooth harrow until the sand and clay are thoroughly mixed, first dry and finally wet. The final mixing should be done, if possible, during rainy weather. When the mixing has been done, the surface is brought to a crown of 1 inch to the foot with the road machine or split-log drag and covered with a thin layer of sand. After two or three rains it may be found necessary to apply more sand. This method produces a smooth, cheap, and satisfactory road suitable for light traffic.

Similar results can be secured by adding sand to a clay road and providing good surface drainage. When building on a clay foundation, it is advisable to plow the clay before adding the sand in order to insure a thorough mixing.

The failure of a sand-clay road is generally due to one of two causes, the use of an unsuitable material or the combination of the sand and clay in wrong proportions. The clay should be of a quality which, while sticky, yet will mix readily with the sand and form a firm bond after the wet mixture has been shaped and dried out. Some clays, such as the "joint" clays, have so little of the plastic or sticky quality that after a rain they quickly separate from the particles of sand and make a dusty road. Where available, the sand selected should be sharp and coarse. With regard to the proportions of sand and clay, any excess of clay above the amount necessary to fill the tiny spaces between the grains of sand will result in a more or less muddy road. Farmers' Bulletin 331,[1] "Sand-clay and Burnt-clay Roads," gives full information on the subject of constructing these roads.

GRAVEL ROADS.

Plate VI, figure 2, illustrates the stages of construction for one type of gravel road. The graded width is 33 feet and the surfaced width is 16 feet. The crown is three-fourths inch per foot.

Section A represents the side ditches, shoulders, and the prepared subgrade, with the center about 10 inches higher than the bottom of the side ditch.

[1] Copies of this publication will be sent free to persons applying to the Secretary of Agriculture, Washington, D. C.

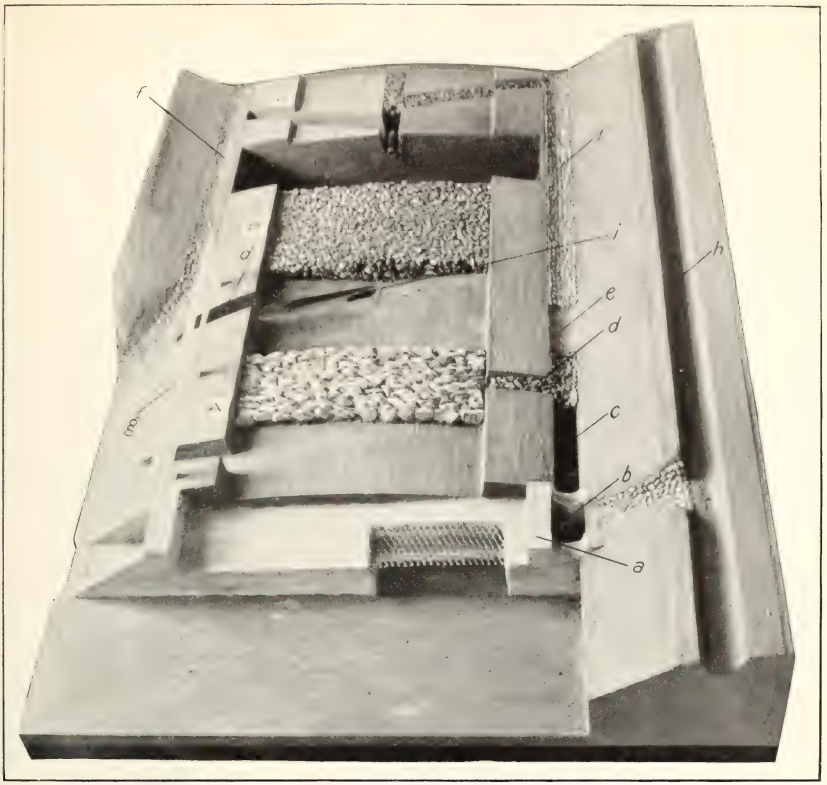


FIG. 1.—MODEL SHOWING VARIOUS METHODS OF ROAD DRAINAGE.

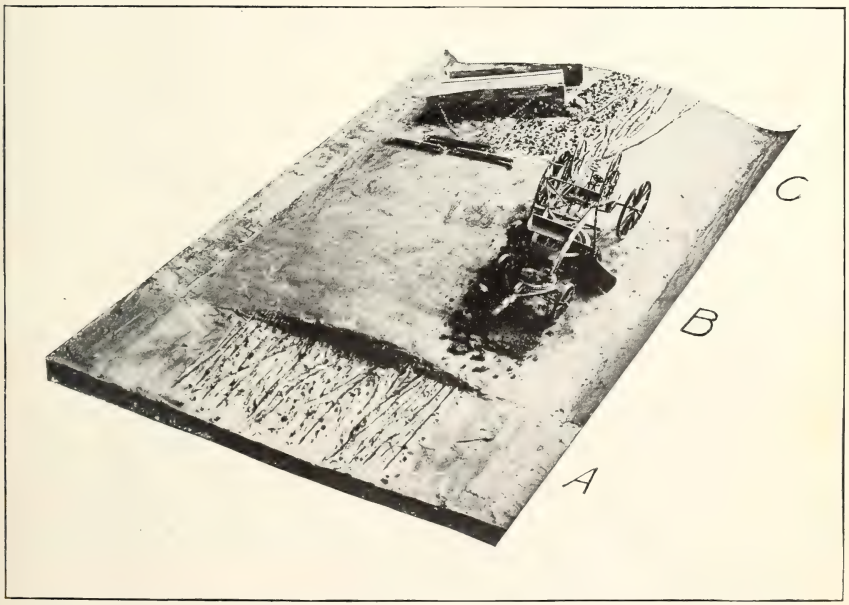


FIG. 2.—MODEL OF AN EARTH ROAD, SHOWING SPLIT-LOG DRAG AND ROAD GRADER IN OPERATION.

FIG. 1.—MODEL OF A SAND-CLAY ROAD.

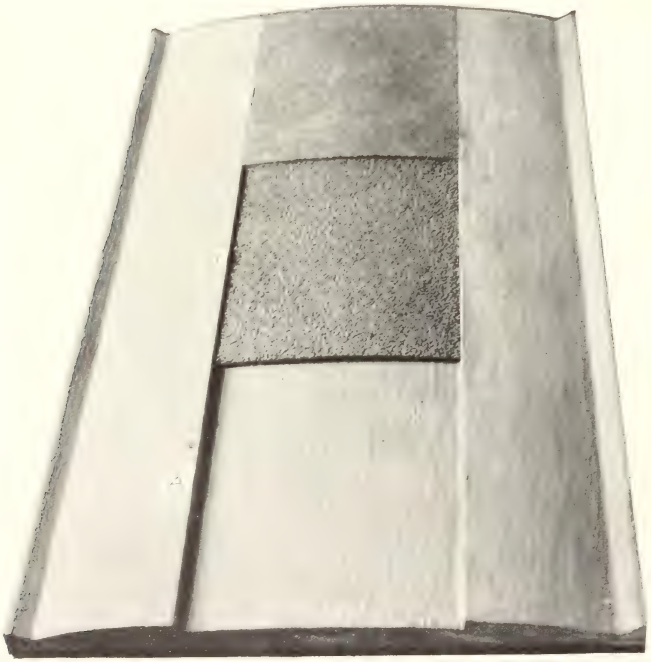


FIG. 2.—MODEL OF A GRAVEL ROAD.

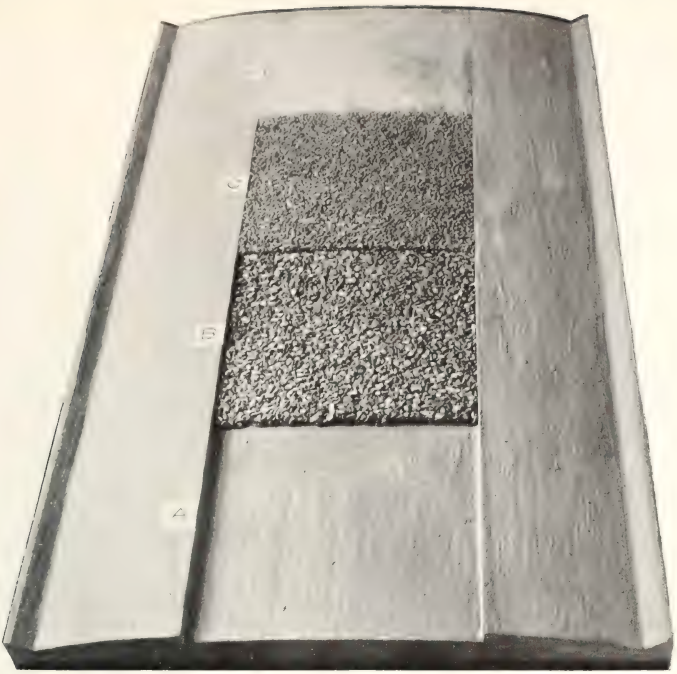


FIG. 1.—MODEL OF A WATER-BOUND MACADAM ROAD.

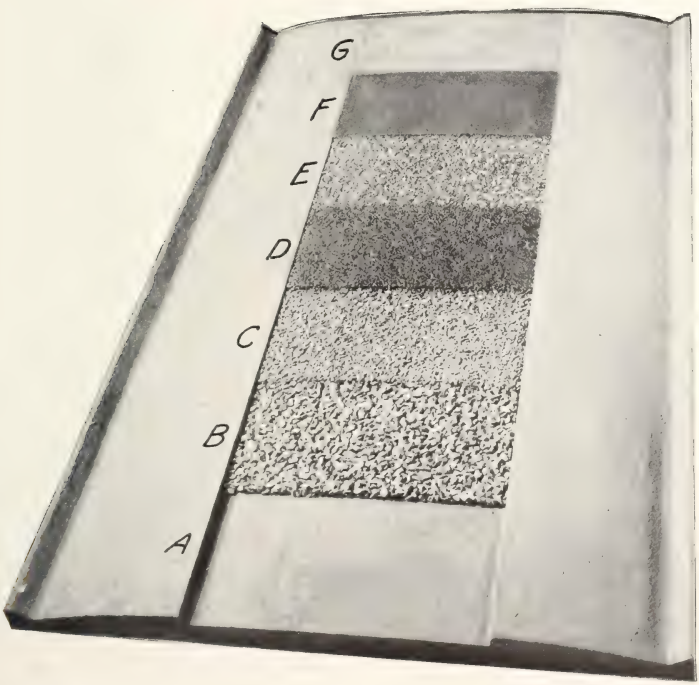


FIG. 2.—MODEL OF A BITUMINOUS MACADAM ROAD—PENETRATION METHOD.

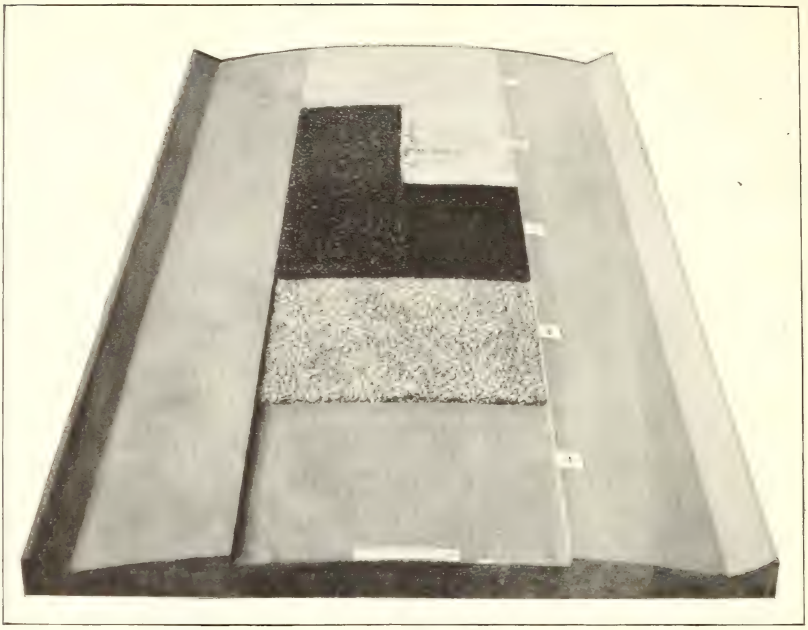


FIG. 1.—MODEL OF A BITUMINOUS MACADAM ROAD—MIXING METHOD.

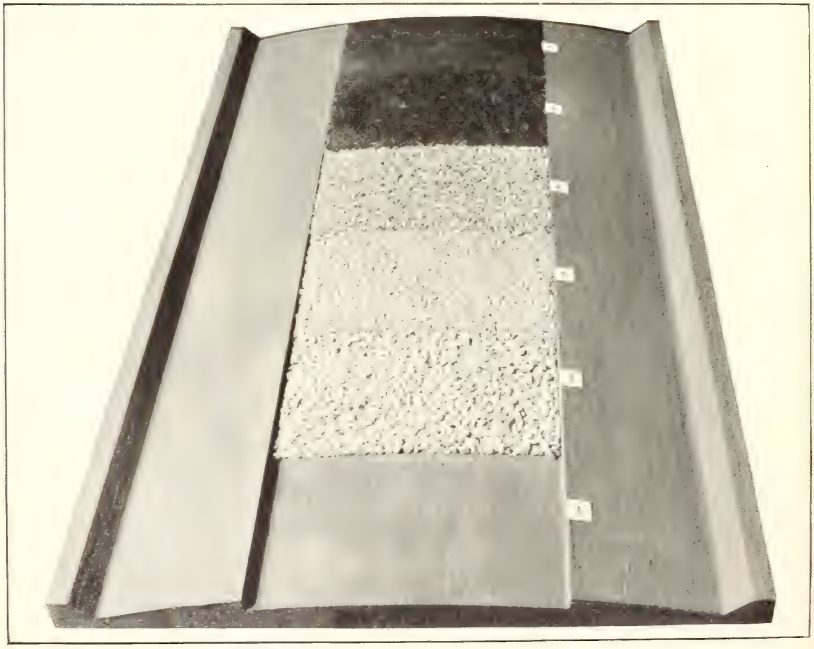


FIG. 2.—MODEL SHOWING A ROCK-ASPHALT MACADAM ROAD.

Section B shows the first course of gravel spread and rolled to a thickness of about 4 inches at the center and 3 inches at the sides.

Section C represents the finished road after the second course of gravel has been spread and compacted. The second course when compacted is 2 inches in thickness at the center and 1½ inches at the sides.

Many gravels as found in nature are not suitable for use on the road, unless modified by the addition or elimination of certain materials. The products of some pits are deficient in bonding materials, such as sand or clay, and at the same time may have an excess of large pebbles. In general, the gravel should be screened and the graded material laid in courses according to the manner of macadam road construction.

MACADAM ROADS.

WATER-BOUND MACADAM ROADS.

Plate VII, figure 1, illustrates the construction of a water-bound macadam road 16 feet wide, 6 inches thick at the center, and 4 inches thick at the sides when rolled. The crown of the finished road as shown is one-half inch to the foot. The road is graded for a width of 33 feet.

Section A represents the prepared subgrade properly crowned and rolled; section B, the first course of broken stone, 4 inches thick compacted; section C, the second course, 2 inches thick compacted; and section D, the finished road.

In preparing for the construction of a road of this type, the procedure given on page 7, for foundation, or subgrade, and shoulders, should be followed. After the subgrade has been prepared, a layer of broken stone of approved size and quality for the first or bottom course should be spread evenly over it to such depth that it shall have, when rolled, the required thickness. The depth of the loose stone may be gauged by laying upon the subgrade cubical blocks of wood of the proper size, and spreading the stone evenly to conform to them.

The roller should be run along the edge of the stone backward and forward several times on each side of the road before rolling the center. If a filler is desired for the bottom course it should be clean, coarse sand, or stone screenings supplemented by the product of the crusher not otherwise used in top or bottom courses. It should be spread uniformly over the surface and then swept in and rolled dry. This process must be continued until no more will go in dry, when the surface should be sprinkled to more effectually fill the voids. Any irregularities or depressions may be made good with broken stone of the size used in the bottom course, and screenings or filler should not be used for this purpose.

The second or top course should be spread on the bottom course to such depth that it shall have, when completed, the required thickness. Blocks of wood of proper size may be used to gauge the depth of the loose stone. Care must be taken to preserve the grade and crown, also to prevent a wavy surface, and all irregularities and depressions ought to be made up with stone the size of the top-course stone. After the surface is true to line, grade, and cross-section, and rolled until the stone ceases to wave in front of the roller, it should be covered with a light coating of screenings, spread on dry, rolled, and swept in. The filler for the top course must be of top-course stone screenings in which the percentage of dust is not excessive. The spreading, sweeping, and rolling in of screenings should be continued until no more will go in dry, after which it is best to sprinkle the road until the top course is saturated. The sprinkler is then followed by the roller. More screenings should be added if necessary, and the sweeping, sprinkling, and rolling continued until a grout has been formed of the screenings, stone dust, and water that shall fill all the voids in the top course and shall form a wave before the wheels of the roller.

When the wave of grout has been produced over the whole section of the road this portion of the road should be left to dry, after which it can be opened to travel. Enough screenings should be spread on top of the macadam to leave a wearing surface about three-eighths of an inch thick.

A miniature steam roller is shown in Plate I of this bulletin. For further information on the subject of macadam roads, Farmers' Bulletin 338,[1] "Macadam Roads," may be of interest.

BITUMINOUS MACADAM ROADS.

Since the coming of the automobile, the resulting aggravation of the dust nuisance, and the consequent raveling of the water-bound macadam roads, numerous methods have been devised to secure a lasting road surface reasonably free from dust and at the same time within the financial means available for main-line country roads.

While the several methods differ greatly as to name and the details of carrying out the work, the fundamental aim of each is the same. This is to secure a smooth, waterproof, and durable surface composed of mineral aggregate, usually broken stone, bonded not only by the mechanical interlocking of the fragments, but by a bituminous material which coats the fragments and fills the interstices. Refined tars, oil asphalts, and fluxed natural asphalts are the binders more commonly employed.

[1] Copies of this publication will be sent free to persons applying to the Secretary of Agriculture, Washington, D. C.

The usual methods of construction are known as the mixing method and the penetration method. In the mixing method a more or less closely graded aggregate is mixed either by hand or machinery with the proper amount of bituminous material before placing it on the road. In the penetration method the wearing or second course of stone is laid and rolled as in ordinary macadam; but instead of applying the screenings, hot bituminous material is poured or sprayed over the stone in sufficient quantity to coat the fragments and penetrate the top course to a depth of 2 or 3 inches. In each of these forms of construction it is customary to spread a second and light application of hot bituminous material over the surface in order to fill the exposed voids completely and make the surface waterproof. A sufficient quantity of pea gravel or stone chips is then added to take up any excess of bitumen, the surface is rolled thoroughly, and the road thrown open to traffic.

PENETRATION METHOD.

Plate VII, figure 2, illustrates the construction of a bituminous macadam road according to the penetration method.

Section A represents the prepared subgrade 16 feet wide, with the crown one-half inch to the foot; section B, the first course of No. 1 stone, 4 inches in thickness when compacted after rolling. This course is partially filled with sand or stone chips when necessary to insure a solid foundation. Section C shows the second course of No. 2 stone, 2 inches in thickness when compacted after rolling; section D, the application of bituminous material at the rate of about 1½ gallons to the square yard; section E, a coating of stone chips which has been rolled; section F, seal coat of bituminous material applied at the rate of about one-half gallon per square yard; and section G, the completed surface, with clean stone chips lightly rolled.

The construction of this road, as far as the completion of the No. 1 and No. 2 courses, is the same as an ordinary macadam road. From that point it varies from the method of construction of a macadam road in that hot bituminous material is flushed into the No. 2 course before the screenings are applied.

MIXING METHOD.

Plate VIII, figure 1, illustrates the construction of a bituminous macadam road according to the mixing method.

Section A shows the prepared subgrade 16 feet wide, with the crown three-eighths inch to the foot; section B, the foundation course of No. 1 stone compacted to a depth of about 4 inches. This course is partially filled with sand or stone chips, as shown in model, when necessary to insure a solid foundation. Section C shows the wearing course before and after rolling, consisting of a properly proportioned

mixture of stone and bituminous material. The stone may be the product of the crusher ranging in size from that which will be retained on a screen having circular openings one-half inch in diameter to that which will pass a screen having circular openings 1¼ inches in diameter. Stone of this size will require from 18 to 20 gallons of bituminous material per cubic yard of stone.

The wearing course is laid to a depth of 3½ inches loose, which will compact to a thickness of about 2 inches by rolling. Section D shows the application of a seal coat of hot bituminous material and clean stone chips, and section E shows the finished surface after final rolling.

SURFACE TREATMENT.

The surface treatment of an old macadam road with bituminous material is shown in Plate IX, figure 1.

Section A shows a disintegrated macadam surface; section B, the surface after sweeping; section C, the application of bituminous material at the rate of about one-half gallon per square yard; and section D, the application of pea gravel or stone chips to the treated surface, completing the treatment.

Before any application of bituminous material is made all loose material should be removed and the road surface should be free from dust, clean and dry. The bituminous material is applied either hot or cold, depending upon the consistency of the material. It may be poured by hand, or by means of a mechanical distributor, and in the former case should be thoroughly broomed into the surface, in order to secure perfect adhesion. Enough stone chips or pea gravel should then be applied to take up any excess bituminous material that may be left on the surface.

RESURFACING MACADAM ROADS.

Plate IX, figure 2, illustrates the reconstruction of a macadam road after it has become badly worn. The macadam width as shown is 16 feet, and the crown is one-half inch to the foot.

Section A represents the worn macadam surface; section B, the surface after spiking; section C, the road after it has been recrowned; section D, the application of new stone of No. 2 size, compacted to 3 inches after rolling; section E, the application of bituminous material by the penetration method at the rate of about 1½ gallons per square yard; section F, a coating of stone chips which has been rolled; section G, a seal coat of bituminous material averaging about one-half gallon per square yard; and section H, the finished surface covered with stone chips or pea gravel.

This model illustrates the usual custom of restoring a macadam road which has become badly worn and rutted, owing to excessive travel and lack of maintenance.

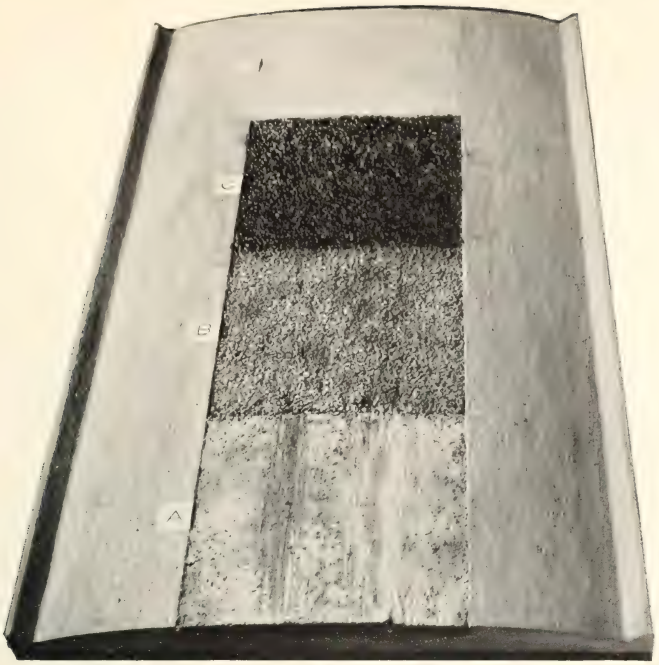


FIG. 1.—MODEL SHOWING REPAIR AND MAINTENANCE OF MACADAM ROADS—SURFACE TREATMENT.

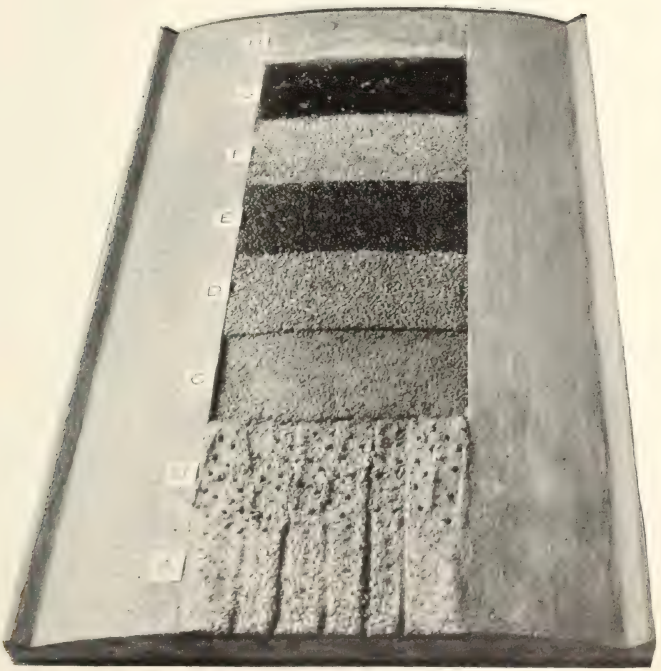


FIG. 2.—MODEL SHOWING REPAIR OF A MACADAM ROAD—RESURFACING ROAD.

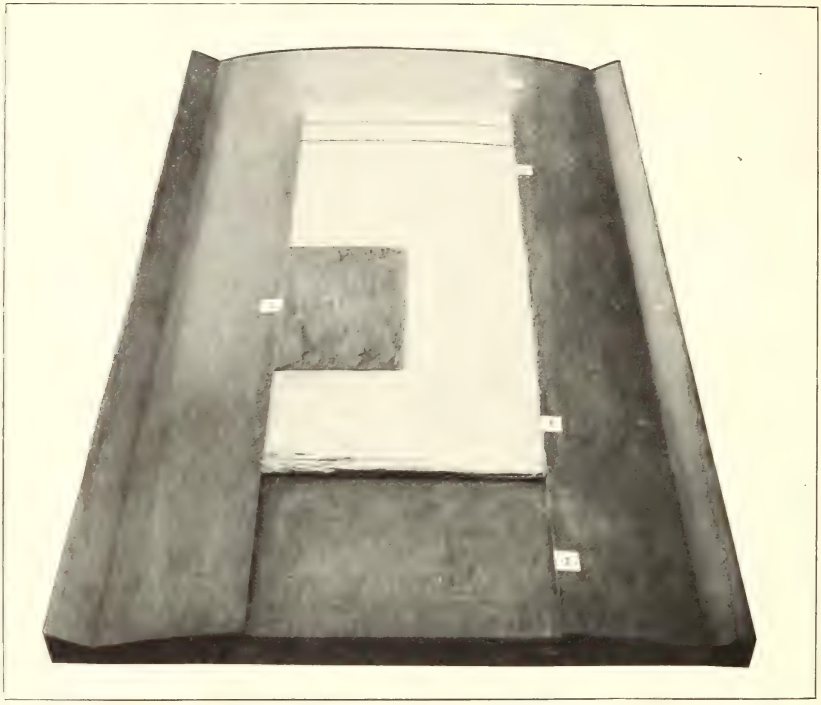


FIG. 1.—MODEL SHOWING CEMENT CONCRETE ROAD.

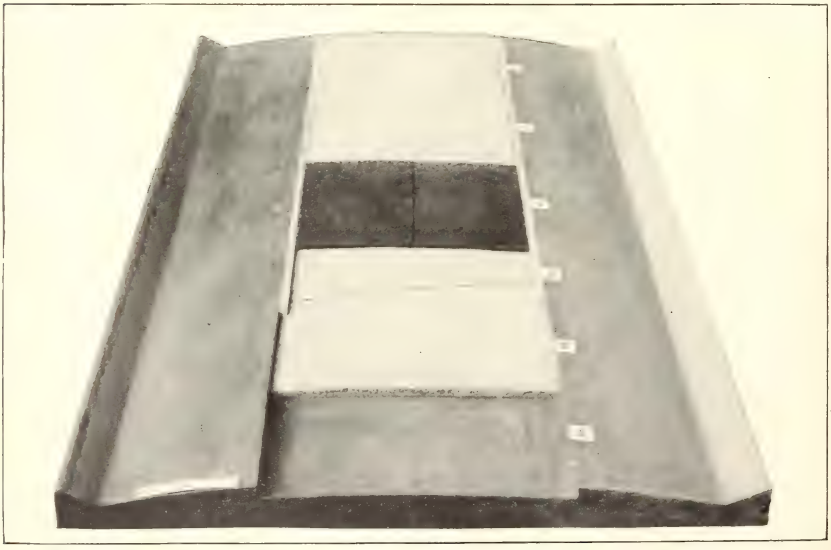


FIG. 2.—MODEL OF A BITUMINOUS CONCRETE ROAD—"TOPEKA" SPECIFICATION.

ROCK-ASPHALT MACADAM ROADS.

Plate VIII, figure 2, represents a rock-asphalt macadam road surfaced to a width of 16 feet. The macadam is compacted to a total depth of 8½ inches and the crown is made one-half inch to the foot. The rock asphalt is spread on the road at the rate of 80 pounds to the square yard.

Section A represents the prepared subgrade; section B, the first course of stone, ranging in size from 2 to 3 inches, with a depth of 3 inches when compacted; section C, the second course of stone, ranging in size from 2 to 3 inches, filled with stone chips or sand, and having a depth of 3 inches when compacted; section D, the third course of stone, ranging in size from 1½ to 2½ inches, with a depth of 2½ inches when compacted; section E, the rock asphalt, to the extent of 40 pounds per square yard, or about three-fourths inch loose, raked and rolled in to fill the voids; and section F shows the finished surface, composed of rock asphalt, spread at the rate of 40 pounds per square yard, which is equivalent to a course about three-fourths inch thick before rolling.

CEMENT CONCRETE ROADS.

Concrete roads are a comparatively new development in the effort to find a material which will successfully withstand both automobile and horse-drawn traffic. Concrete pavements were laid first in 1869 in Grenoble, France, where many streets are still paved with this material. In this country the first use of the concrete pavement was probably in Bellefontaine, Ohio, where several sections were laid in 1893 and 1894.

A large mileage of concrete roads has been built in Wayne County, Mich. These roads are built of a 1:1½:3 mixture throughout, with a minimum thickness of 7 inches. The width of the surfaced roadway varies from 9 to 24 feet. The county road officials are very well pleased with this form of construction, and are building many more miles of it.

In other instances a leaner concrete is used, and the surface protected by a cushion coat of some bituminous binder with sand, fine gravel, or screenings. This surface coating is renewed as often as may be necessary.

Plate X, figure 1, illustrates the construction of a concrete road graded to a width of 33 feet and paved to a width of 16 feet. The concrete is placed to a depth of 7 inches in the center and 4 inches at the sides. The crown of the road is three-eighths inch to the foot. Section A represents the prepared subgrade; section B the fresh concrete placed in position, mixed in the proportion of 1:1¾:3; section C, a 2-inch earth blanket, placed to minimize evaporation while cur-

ing: section D shows various types of expansion joints, namely, wood, felt, and bituminous filler; section E, the bituminous carpet coat consisting of one-third to one-half gallon of bituminous material per square yard and sufficient "torpedo" sand or stone chips to provide a satisfactory wearing surface.

BITUMINOUS CONCRETE ROADS—"TOPEKA SPECIFICATION."

Plate X, figure 2, represents a type of bituminous concrete construction. It is preferably laid over a concrete base to the depth shown, but is frequently constructed over a well-consolidated macadam or crushed-stone base.

Section A shows the subgrade; section B, the concrete foundation composed of broken stone or gravel concrete mixed in the proportion 1:3:7 and having a finished thickness of 6 inches. Section C demonstrates the manner of constructing the curbs. It also shows the joint left at the end of each day's work. Section D shows the layer of bituminous concrete before and after rolling. The composition of this concrete is commonly as follows:

	Per cent.
Bitumen soluble in carbon bisulphide	7–11
Mineral aggregate passing a 2-mesh sieve	100
Passing 2-mesh sieve and retained on 4-mesh sieve	5–10
Passing 4-mesh sieve and retained on 10-mesh sieve	8–22
Passing 10-mesh sieve and retained on 40-mesh sieve	25–55
Passing 40-mesh sieve and retained on 200-mesh sieve	18–30
Passing 200-mesh sieve	5–11

Section E shows the application of a seal coat with stone chip dressing. The amount of bituminous material applied should not exceed one-half gallon to the square yard, and the seal coat is frequently omitted when the bituminous concrete is sufficiently dense to warrant the omission.

Section F shows the finished surface.

PAVED ROADS OTHER THAN CONCRETE.

Paved roads are sometimes advisable where there is heavy traffic. The materials which have been adapted to country roads during the past years are brick, asphalt block, granite block, and a small stone block extensively used in Germany and known as "kleinpflaster."

A good paving brick laid on a sand cushion with a substantial concrete foundation makes a road well adapted to both horse-drawn and motor traffic. The first cost of such a road is generally high, but this is largely offset by its durability and low maintenance cost.

Asphalt blocks are molded from sand, broken stone, and asphalt under pressure into rectangular blocks, which are laid on a concrete foundation somewhat in the same manner as brick. The asphalt blocks are more resilient than the brick and consequently more free

from noise. They have as yet not been used to any great extent on the country roads of the United States. The small sett, or "kleinpflaster," pavement of Germany is as yet almost unknown in this country. A hard, tough rock, preferably basalt or diabase, is broken by machinery into cubes 3 to 4 inches in size. These are placed on a light sand cushion, with a concrete or old macadam base as foundation. In Germany they are generally laid in an oyster shell or mosaic pattern, while in Hungary and Austria they are laid in rows at 45 degrees to the axis of the road. This pavement may be laid at a fairly low first cost, is not expensive to maintain, is neither noisy nor slippery, and is well adapted to mixed traffic.

ASPHALT-BLOCK ROADS.

Plate XI, figure 1, represents an asphalt-block road.

Section A shows the subgrade, and beginning with section B is shown the concrete curb. Section B shows the concrete base 6 inches thick, mixed in the proportion 1 : 3 : 7; section C, the cement mortar bed, one-half inch thick, composed of 1 part of slow-setting Portland cement and 4 parts of sand; section D, the asphalt block surface. The asphalt blocks are 5 inches wide, 12 inches long, and 2 inches thick. In section E the surface has been covered with sand which has been screened through a $\frac{1}{8}$-inch mesh screen. This sand carpet is used to fill the joints between the blocks, and should be allowed to remain for 30 days. The surface should then be swept clean.

BRICK ROADS.

Plate XI, figure 2, illustrates the construction of a 28-foot roadway, 14 feet of which is a brick road with 6-inch concrete curbings. There is a 3-foot earth shoulder along one edge of the brick roadway, and the remaining 11 feet form an earth road on the opposite side. The earth road has a slope toward its ditch of 1 inch to the foot. The outer 11 feet of the brick roadway has a slope of three-eighths inch to the foot, but the slope of the inner 3 feet is less, forming the crown of the road. The earth road is preferred in dry weather by many drivers of horses.

Section A illustrates the prepared subgrade for the brick roadway; section B, the concrete curbing placed along the edges of the pavement; section C, a stone base 6 inches deep, and section D, a concrete base 6 inches deep. Either of these bases may be used, although the concrete is generally preferable. This base course of the road may vary in thickness from 4 to 8 inches, according to soil conditions, but 6 inches is in most general use. Section E shows the sand cushion, about 2 inches deep; section F, the brick laid and rolled but not grouted; section G, the expansion joint between the brick and

the curb; and section H illustrates the grouted brick surface ready for travel. In addition, a properly constructed mixing box is shown, in which the grout is prepared.

CULVERTS AND BRIDGES.

The first highway bridges in this country were constructed of wood and required much attention for repairs and renewals. Later, wrought and cast iron were combined with wood in what became known as combination bridges. The present general demand for structures composed of more permanent materials is due largely to the expense and inconvenience of maintaining those of wood or combined wood and iron. In many sections there is also need for stronger bridges because of the increase in weight of traffic. Steel possesses the requisite strength, but it is subject to rust and rapid deterioration if not protected with a durable covering. Portland cement concrete is quite free from objectionable qualities, and by skillfully combining steel and concrete in highway bridges it is possible to utilize the good features of each material, and at the same time overcome their disadvantages. Reinforced concrete bridges may be made strong and durable. The concrete can be cast in any shape, and the surface finished in many different ways to secure a pleasing appearance. Such bridges cost more in the beginning, but practically nothing to maintain, while those of wood, or steel not incased in concrete, require frequent painting and renewal of parts.

Culverts constructed of stone and concrete are generally superior to those made of pipe and are less liable to injury by freezing. Hard-burned bricks are suitable for culvert material in localities where they are cheap and where stone or concrete materials are not easily available. Brick culverts are not so durable as those made of stone or concrete, especially in cold climates, where freezing is likely to occur.

Plate XII, figure 1, represents a bridge of the incased I-beam type, having a span of 24 feet, height of 6 feet, and width of roadway of 20 feet. The steel I-beams are 18 inches in depth, weigh 55 pounds per linear foot, and are spaced 3 feet 3 inches apart. The concrete is held firmly to the bottoms of the beams by wires of No. 10 gauge in the form of vertical loops spaced 8 inches apart. Lettered cards are used to designate the parts, as follows:

A, 6½-inch reinforced concrete floor slab; B, ½-inch twisted steel bars, spaced 8 inches apart and resting on the I-beams; C, steel I-beams; E, wooden forms (framing 3 by 6 inches, 3 feet on centers; boards 1¼ by 8 inches); F, parapet and railing; G, wing walls (top thickness, 12 inches, bottom thickness varies with height of wall, generally not less than four-tenths of height); H, footing (course obtained by adding 1 foot to thickness of abutment wall at base,

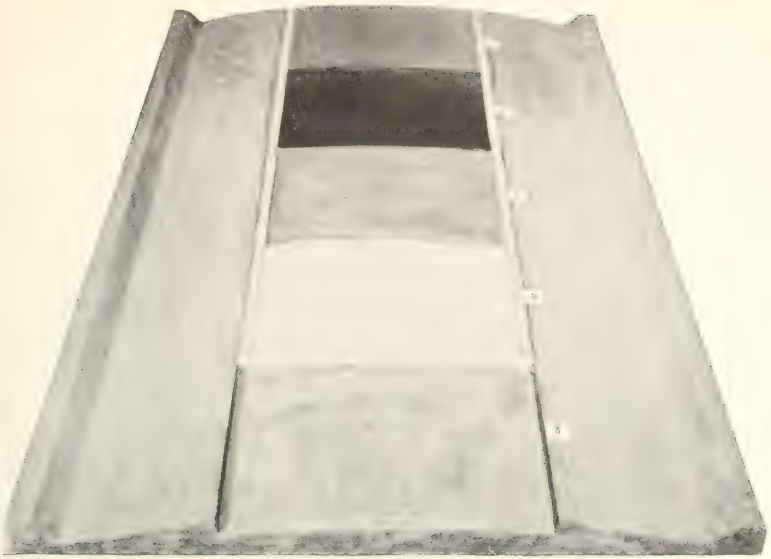


FIG. 1.—MODEL SHOWING AN ASPHALT-BLOCK ROAD.

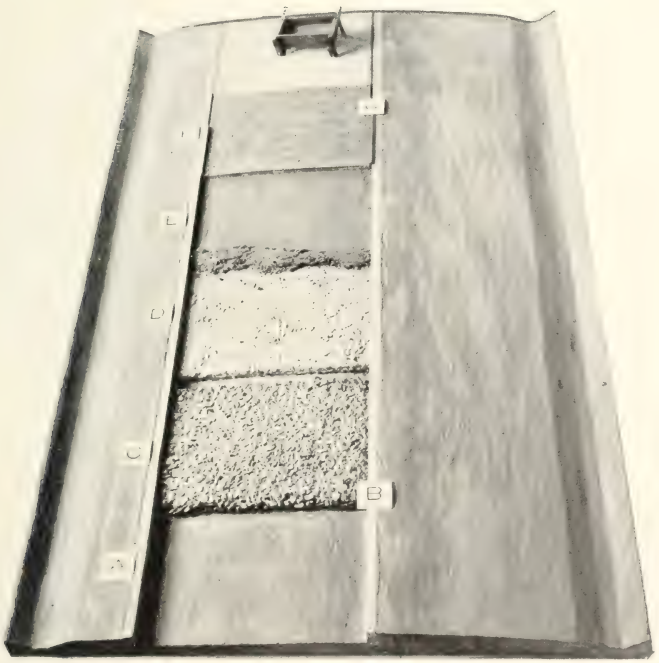


FIG. 2.—MODEL OF A BRICK ROAD.

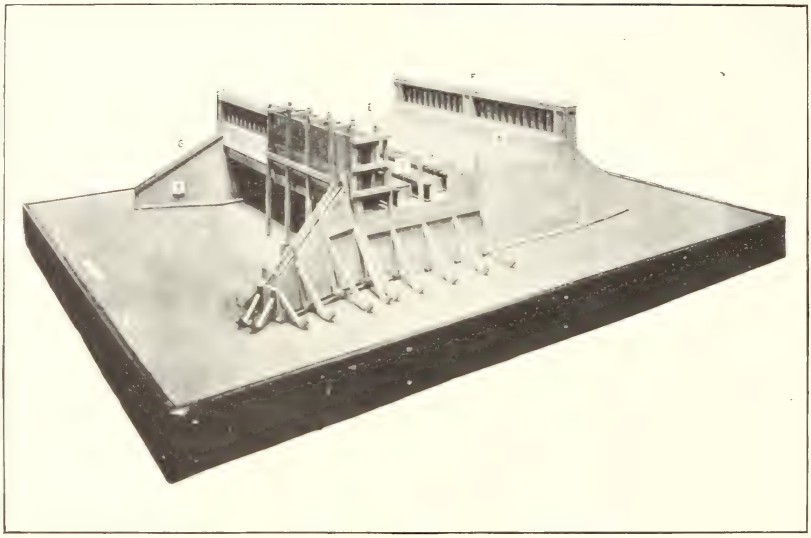


FIG. 1.—MODEL SHOWING REINFORCED CONCRETE BRIDGE—INCASED I-BEAM TYPE.

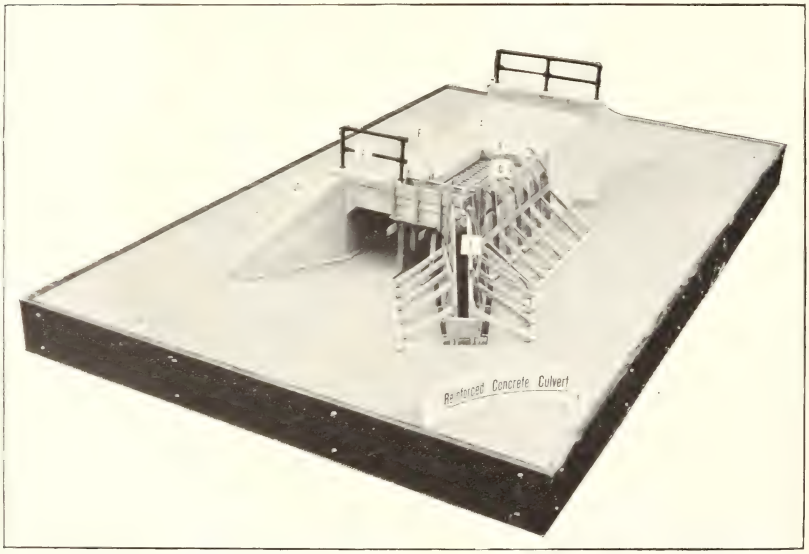
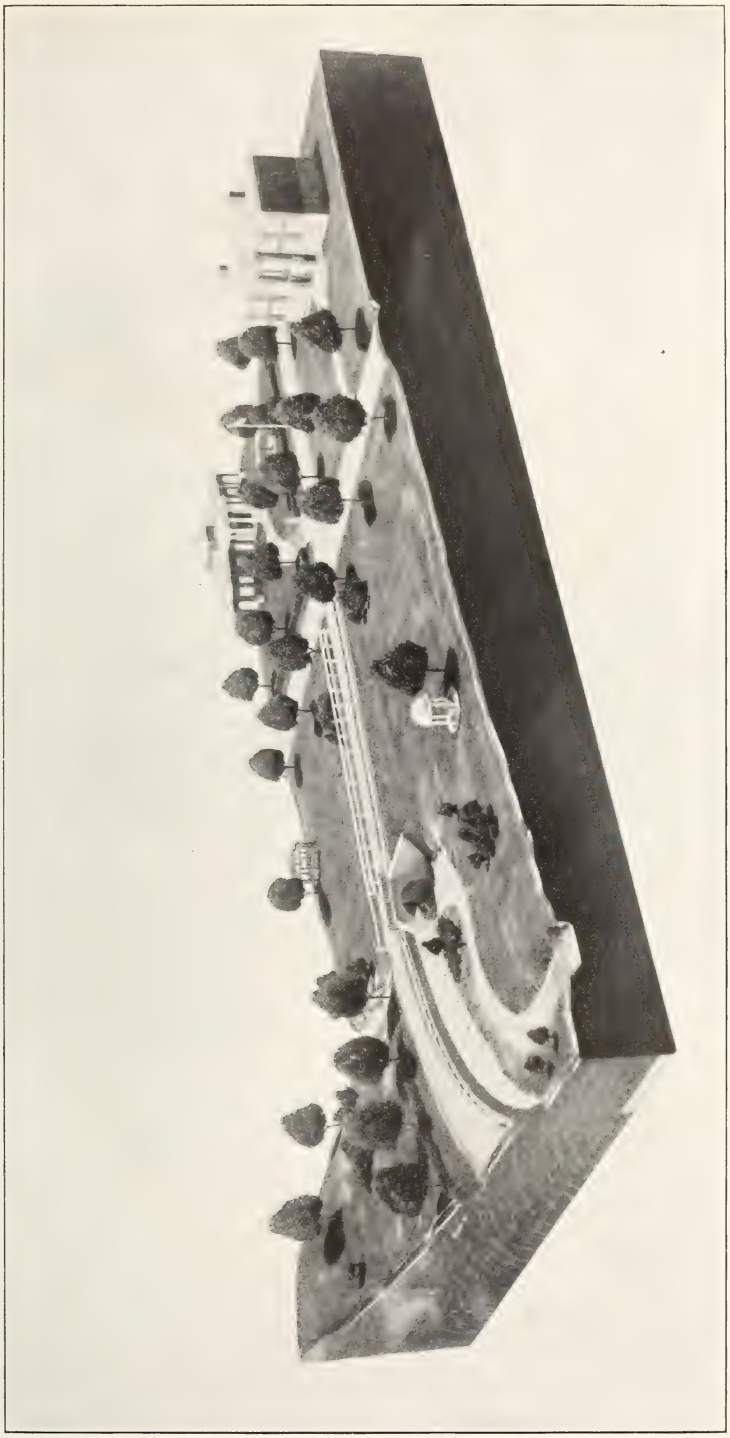


FIG. 2.—MODEL SHOWING REINFORCED CONCRETE CULVERT—SLAB TYPE.



MODEL SHOWING ROADSIDE TREATMENT.

depth made such that footing will extend to rock, hardpan, or other suitable foundation material; where rock is not found the depth is governed by character of soil and topographical features).

The concrete is made of Portland cement, clean sand, and hard broken stone or gravel, mixed in the following proportions:

Superstructure, 1:2:4 (size of stone, ¼ to 1 inch).
Abutments above footings, 1:2½:5 (size of stone, ¼ to 2½ inches).
Footings, 1:3:6 (size of stone, ¼ to 2½ inches).

Plate XII, figure 2, represents a reinforced concrete culvert having a span of 8 feet and height of 4 feet, with 24-foot width of roadway. Lettered cards are used to designate the parts, as follows:

A, reinforced concrete floor slab, 10½ inches in thickness; B, ⅝-inch twisted steel bars, 1½ inches from the underside of the floor slab, spaced 6 inches center to center and parallel to the center line of the roadway (there are also ½-inch twisted steel bars, 12 inches center to center, extending the full width of the bridge perpendicularly to the center line of the roadway); C, abutment wall (thickness at top, 13 inches; thickness at base, 1 foot 10 inches); D, wing walls (thickness at top, 10 inches; thickness at base, 1 foot 1 inch to 2 feet 3½ inches); E, forms (framing, 2 by 4 inches, 3 feet on centers; boards, 1¾ by 8 inches); F, pipe railing (2-inch galvanized-iron pipe protected by painting); G, concrete parapet (top thickness, 1 foot 6 inches); H, footing (2 feet 6 inches wide by 3 feet or more in depth, depending on foundation material).

The concrete is made of Portland cement, clean sand, and hard broken stone or gravel, mixed in the following proportions:

Superstructure, 1:2:4 (size of stone, ¼ to 1 inch).
Abutments above footings, 1:2½:5 (size of stone, ¼ to 2½ inches).
Footings, 1:3:6 (size of stone, ¼ to 2½ inches).

Any kind of surfacing or pavement may be used over these bridges.

ROADSIDE TREATMENT.

Plate XIII has been designed to emphasize various methods of roadside treatment. Well-trimmed trees furnish shade along the roads and aid in preventing the road surfaces from drying out and raveling. Neat signposts stand at the crossroads, and in place of a fence the house lawn is divided from the road by a sightly hedge. The use of the guardrail is shown, with the concrete retaining wall where the road follows the creek bank. A well-constructed concrete arch bridge is a feature of the model. The slopes of the fill extending from the bridge to the crossroad are sodded to prevent slides. Traffic on the fill is protected by double guardrails.

The schoolhouse represents a type of the modern consolidated country school. Its concrete walk to the road furnishes a good

example in the use of the small culvert where the walk leads over the ditch before reaching the road. This same use of the culvert is made at the driveway entrance to the house. Architectural features of Monticello, the former home of Thomas Jefferson, were followed in the construction of this dwelling. The rustic summer house and the spring house in its cool white furnish pleasing sights across the fields, which have been cleared of undergrowth and left with only a few well-placed trees and shrubs.

ROAD MACHINERY.

Many good roads were built before the invention of road-building machinery, but modern machinery has done much to simplify the process and reduce the cost of road construction. The power-driven road roller has made possible the construction of a macadam road in a few days or weeks, where formerly traffic was required to make its way laboriously over the loose stones for months before the surface became even reasonably consolidated.

The steam road roller was invented by M. Louis Lemoine, of Bordeaux, France. The French Government granted him a patent in 1859. The first English patent was granted to Messrs. Clark and Bathe in 1863. The first steam road roller used in the United States was imported from England in 1868, and its first use was on the United States arsenal grounds in Philadelphia.

The stone crusher has greatly reduced the labor of preparing broken stone. It was the invention, in 1858, of Eli Whitney Blake, of New Haven, Conn. He was a nephew of Eli Whitney, the inventor of the cotton gin. Mr. Blake's crusher was used first in Central Park, New York City, in crushing rock for concrete. In 1859 the city of Hartford, Conn., purchased one of these crushers for use in the improvement of its streets and roads. This was the first successful application of mechanical power to breaking stone for road-building purposes.

CRUSHER PLANT.

Figure 1, represents a portable stone-crusher plant. A crusher plant is indispensable in the construction of first-class broken-stone roads, and if such work is to be done well and cheaply the plant must be complete and conveniently arranged.

Sometimes the crusher can be located so near the quarry that the rock may be sent down grade in tramcars and delivered to the mouth of the crusher by gravity, thus saving much hand labor. The crusher should be provided with an elevator for delivering the broken stone to the screen, which separates the material into proper sizes. The screen should be in three sections. The first section usually contains openings 1 inch in diameter. Through these openings the fragments of stone known as "screenings" drop into a bin corresponding to

that marked A in the model. The openings of the second section of screen are 2 inches in diameter. The stones which pass through these openings into bin B are called No. 2 stone. The third or last section of screen has 3-inch openings, passing No. 1 stone into bin C. The tailings, or larger stones, will be forced through the opening at the end of the screen, from which they will drop into the tailings conveyor, to be crushed finally or eliminated from the work. The jaws of the crusher should be set so as to make as few tailings as possible. The sizes of these screen openings may vary, according to the quality of the stone. For instance, in crushing a hard stone, the openings of each section may be of slightly smaller diameter, since it is customary

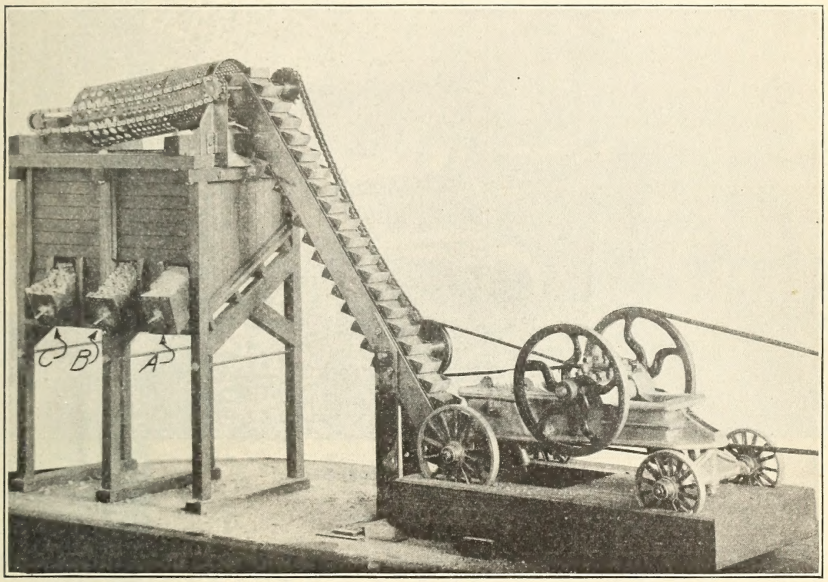


FIG. 1.—Model of portable crushing plant in operation.

to crush a hard stone to somewhat smaller grades than a softer material.

When soft stones are being crushed, a dust jacket having a $\frac{1}{4}$-inch mesh may be placed over the first section to eliminate dust from the screenings. The bins A, B, and C, for receiving the various sizes of crushed rock, should be provided with slanting metal bottoms and sliding doors, so that the material may be loaded into wagons by gravity.

Two types of crusher are commonly used, one the jaw crusher, shown in figure 1, and the other the gyratory crusher. The jaw crusher is generally used for portable plants. In this machine one of the jaws moves backward and forward by means of a toggle joint and an eccentric, and the stone descends as the jaw recedes. As the

jaw returns it grips the stone and crushes it. The maximum size of the product is determined by the distance between the jaw plates at the lower edge.

The essential feature of the gyratory crusher consists of a perpendicular iron shaft which revolves with an eccentric motion. Around the top of the shaft, which is conically shaped, is a hollow iron receptacle somewhat resembling an inverted bell. By the eccentric motion of the shaft the conical portion crushes the rock alternately against different sides of the inner surface of the bell.

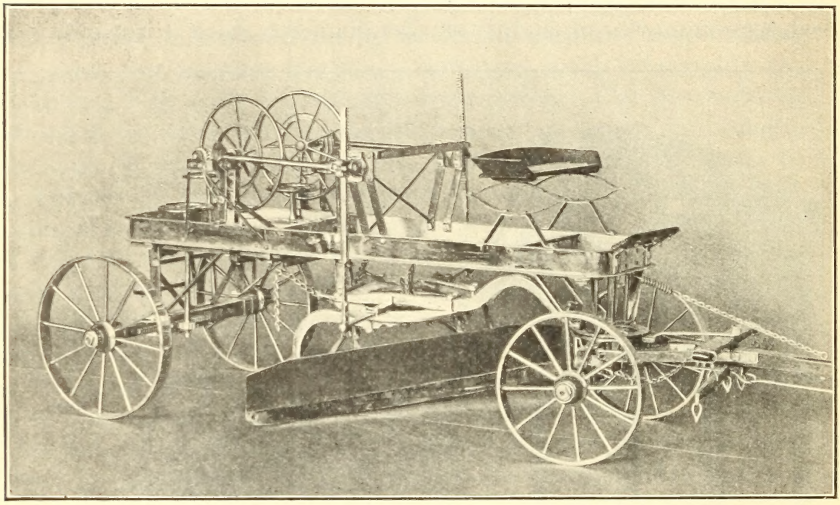


FIG. 2.—Model of road grader.

ROAD GRADERS.

Figure 2 shows in miniature a road grader which is used in building earth roads and in preparing the subgrade for hard-surfaced roads. The frame supports an adjustable scraper blade, the front end of which may be used to plow a furrow, while the rear end pushes the earth along the surface of the blade toward the center of the road or distributes it smoothly. The blade may be set at any angle or tilted either backward or forward according to the work to be done.

It is advisable to use the grader when the ground is soft, preferably in the early summer, in order to give the loose earth time to settle and pack before the fall rains begin. If the work is done in the fall not more than 3 or 4 inches of loose earth should be put on at one working.

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